# SOME FACTORS AFFECTING THE TOXICITY OF HYDROCYANIC ACID FOR INSECTS.

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During the last twenty years a vast amount of work has been done on the control of injurious insects by the use of hydrocyanic acid. Inasmuch as little quantitative work seems to have been done on the influence of environmental factors, such as temperature and humidity, upon the toxicity of HCN to insects, and since the relation of concentration of cyanide to length of exposure also does not seem to have been thoroughly investigated, it was thought advisable to study these points in some detail.

## Apparatus and Method.

To determine the effect of concentration of cyanide, length of exposure, temperature and humidity upon the toxicity of HCN to insects, apparatus by which all these factors can be controlled or varied must be employed. In the present experiments, such apparatus was devised and proved to be very satisfactory.[2]

The apparatus, as shown in Fig. 1, consists of the following units: (*A*) flow regulator (one-inch glass tube 5 feet long); (*B*) humidifying unit, consisting of two half-liter bottles; (*C*) two flow meters; (*D*) generating flask; (*E*) half-liter bottle used as a fumigation chamber, placed in a water bath; (*F*) a small absorption bottle used for collecting samples of gas for analysis; (*G*) a one-liter bottle filled with NaOH for absorbing the gas. The outlet at H is attached to a suction pump.

The air flows in the direction indicated by the arrow. The rate of flow can be regulated by raising or lowering the glass tube

[1] This work was done in coöperation with the American Cyanamid Sales Company.

[2] The writers wish to acknowledge the assistance given by Mr. K. D. Ashley, of the Chemical Staff of the American Cyanamid Sales Company, who furnished valuable suggestions for devising the apparatus and for the colloidal silver iodide method of analysis.

(*a*). The humidifying unit is filled with either distilled water or various strengths of sulfuric acid to give the desired humidity. The air, after passing through the flow regulator, passes over the humidifying unit and through the first flow meter, which gives

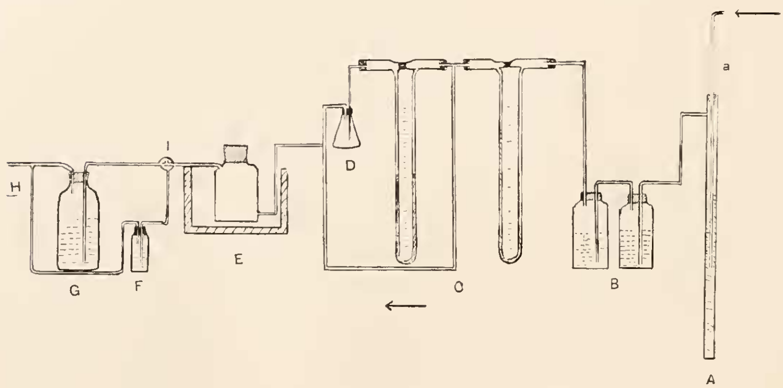


FIG. 1. Apparatus used in determining the toxicity of HCN to insects.

the total rate of flow in liters per hour. The air line is divided after leaving flow meter No. 1; part of the air passes directly into the gassing chamber *E*, the remainder of the air goes through the second flow meter, thence to the generating flask *D*, which contains the source of HCN (calcium cyanide or liquid HCN). The air saturated with HCN mixes with the pure air in the tube leading to the gassing chamber *E*. The apparatus is so designed that the concentration of HCN can be regulated by controlling the amount of air which passes through the second flow meter. The reading of the second meter gives the rate of flow of air through the generating flask. The air-gas mixture, after leaving the gassing chamber, passes into the absorption bottle *G* containing a concentrated solution of NaOH for the purpose of absorbing the HCN, thus preventing any escape of the gas into the room.

To collect a sample of gas for analysis, the gas-air mixture is passed through a small absorption bottle *F* by turning a two-way stopcock *I*. In this work two methods of analysis were used. The first method consists of collecting one liter of gas in a 10 per cent. NaOH solution and titrating with silver nitrate.

By the second method the HCN is passed into an alkaline, colloidal solution of silver iodide, which is made by adding potassium iodide to a known normality of silver nitrate. The time which is required to decolorize the solution is taken by means of a stopwatch. The first method of analysis, is perhaps, more accurate, but as it requires more time than the second, it was used only as a check on the AgI method. By the use of the second method, several samples could be tested during one exposure, so that accurate record could be kept of the concentration of HCN.

The insects used in the tests were kept in a container in a water bath maintained at a desired temperature for 1 hour before fumigating and the fumigation chamber was kept at the same temperature. After fumigating the insects, they were replaced in the water bath until the following morning, when they were removed and the mortality was determined. Throughout this work, unless otherwise stated, granular calcium cyanide was used as a source of HCN.

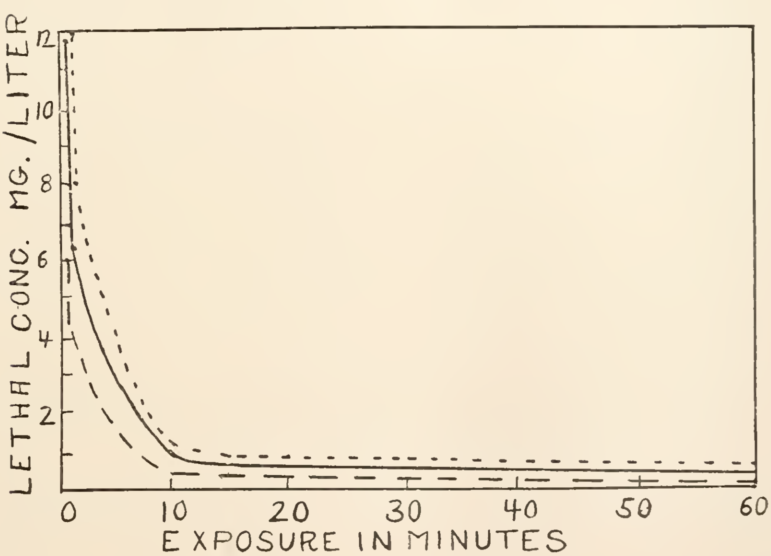


FIG. 2. Curve showing the relation of concentration of HCN to length of exposure and the effect of temperature upon the toxicity of HCN to *Macrosiponiella sanborni*. Solid line, 25° C.; dotted line, 20° C.; broken line, 30° C.

## Relation of Concentration of HCN to the Length of Exposure.

Experiments were carried out to determine whether a low concentration of cyanide for a long period of time was more fatal than a high concentration for a short period of exposure. When using $Ca(CN)_2$ under field conditions, where one is not able to obtain a long period of exposure, it is necessary to use a very high concentration.

The results obtained from more than a thousand tests with two species of aphids and one species of thrips, show that concentration and length of exposure are inversely related up to a certain time, *i.e.*, toxicity = concentration × the time. Beyond a period of 15 minutes it seems that concentration is independent of the time, as it takes practically the same concentration to kill in one hour as in 30 minutes (Figs. 2, 3 and 4).

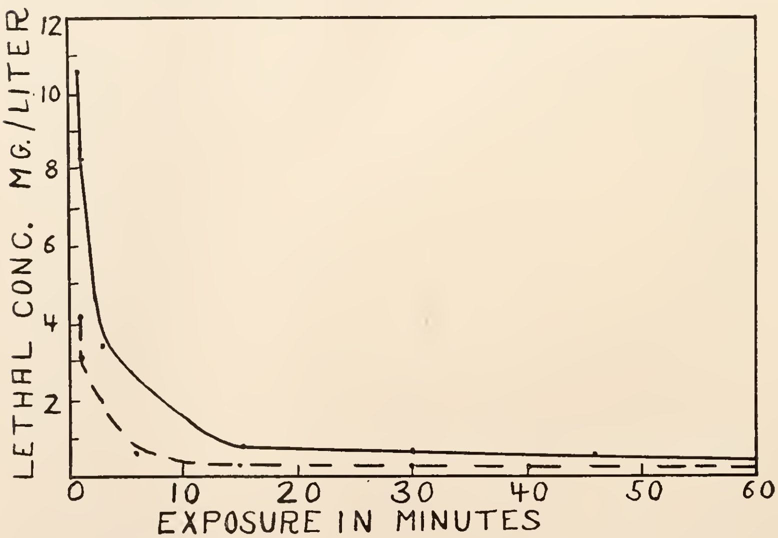


Fig. 3. Curve showing the relation of concentration of HCN to length of exposure and the effect of temperature upon the toxicity of HCN to *Aphis rumicis*. Solid line, 25° C.; broken line, 30° C.

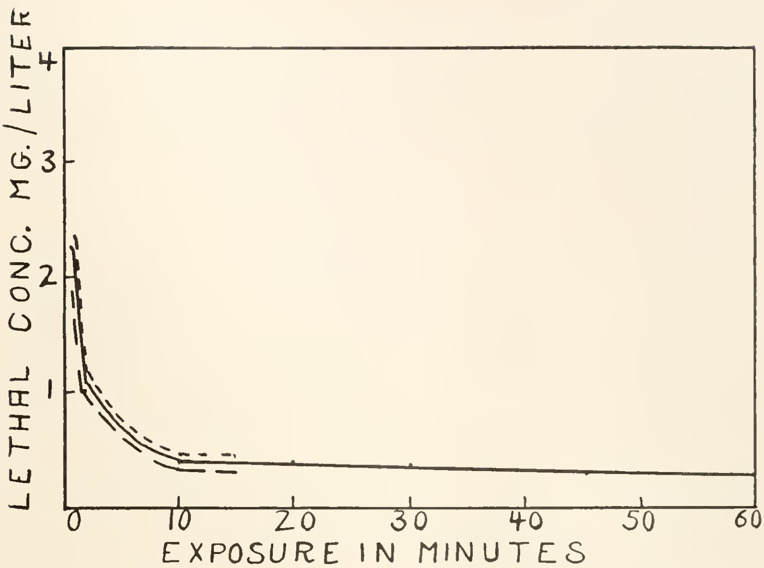


FIG. 4. Curve showing the relation of concentration of HCN to length of exposure and the effect of temperature upon the toxicity of HCN to *Thrips tabaci*. Solid line 25° C.; broken line, 30° C.; dotted line, 20° C.

## TEMPERATURE.

It is known that metabolic processes increase with increase in temperature. With an increase in metabolic activities, we would expect an increase in the susceptibility of the insect to HCN. That such appears to be the case is shown in Figs. 2, 3 and 4. It may be noted from these figures that the effect of temperature is more pronounced with the shorter exposures.

Throughout the experiments on aphids, it was noted that the young organisms and the winged adults were more susceptible than the wingless adults. These results coincide with Child's [1] idea that the physiologically young organisms have a higher rate of metabolism than the older animals and are more susceptible to cyanide. In the case of thrips, however, the adults seem to be easier to kill than the young.

[1] Child, "Senescence and Rejuvenescence," Chicago University Press, 1915.

## Humidity.

Several humidity experiments were conducted using *Aphis rumicis*, *Sitophilus granarius* and *S. oryza* under various relative humidities, other factors being the same. The result of these experiments indicate that humidity is not an important factor in determining the toxicity of HCN.

## Comparison of the Toxicity of Liquid HCN and $Ca(CN)_2$.

During the course of the experiment, the question arose as to the comparative toxicity of hydrocyanic acid resulting from the action of water vapor on $Ca(CN)_2$ and the HCN volatilizing from liquid HCN. It is known that in addition to HCN, there are other compounds, such as ammonia and hydrogen sulphide, which arise from hydrolysis of $Ca(CN)_2$, and so it was thought advisable to ascertain what effect these foreign gases would have upon the toxicity of HCN.

The results indicate that the pure HCN coming from liquid HCN is slightly more toxic than the gas mixture which arises from $Ca(CN)_2$. These results are also confirmed in a number of experiments by adding slight quantities of $NH_3$ and $H_2S$ to the gas which arises from liquid HCN, showing that there is some antagonistic action between the ammonia, hydrogen sulphide and HCN, thus lowering the toxicity of HCN.

## Effect of Methyl Acetate on the Toxicity of HCN.

Some insects, such as *Melanoplus differentialis*, when placed in a sublethal concentration of HCN, close their spiracles and thus prevent, to a certain extent, the entrance of the cyanide gas.

It was thought that if some chemical could be mixed with the HCN, which would keep the spiracles open, the insects would be more easily killed by cyanide than if the spiracles are allowed to close. Methyl acetate is found to keep the spiracles open in *M. differentialis* when the insect is placed in an atmosphere of HCN. Experiments were conducted to determine what effect the addition of a small amount of methyl acetate would have upon the toxicity of pure HCN. The only insects available at the time of the experiments were *S. granarius* (grain beetle), and it was not determined whether or not the insects close their spiracles. However, when the methyl acetate was added to liquid HCN, the average kill as shown from ten experiments was 77.4 per cent. as compared with a 59 per cent. kill when pure HCN was used.

## Summary.

A detailed study was made of the toxicity of HCN for certain insects. The insects used in this work were two species of aphids, *Aphis rumicis* and *Macrosiphoniella sanborni*, one species of thrips, *Thrips tabaci*, and two species of grain beetles, *Sitophilus granarius* and *S. oryza*. Apparatus by which all factors can be controlled or varied was employed.

The results of over a thousand experiments indicate that, within certain limits, concentration and length of exposure are inversely related or that toxicity = concentration × the time.

The higher the temperature, the more susceptible were the insects; this susceptibility was more pronounced with the shorter exposures.

Present indications are that humidity is not an important factor affecting the toxicity of HCN. Comparative studies on calcium cyanide and liquid cyanide show that the liquid HCN is more toxic than the gases from hydrolysis of calcium cyanide. A small amount of methyl acetate added to liquid HCN seemed to increase the toxicity of the gas arising from the liquid HCN, which may be due to the fact that a small amount of methyl acetate kept the spiracles open, while in pure HCN the spiracles were quickly closed.